

CAPACITOR-TYPE MICROMETEROID DETECTORS

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The Metal Oxide Semiconductor (MOS) Capacitor Micrometeroid Detector consists of a thin dielectric capacitor fabricated on a silicon wafer. In operation, the device is charged to a voltage level sufficiently near breakdown that micrometeoroid impacts will cause dielectric deformation or heating and subsequent arc-over at the point of impact. Each detector is capable of recording multiple impacts because of the self-healing characteristics of the device. Support instrumentation requirements consist of a voltage source and pulse counters that monitor the pulse of recharging current following every impact. The devices are suitable for micrometeoroid detectors on satellites because of their wide temperature tolerance, low power requirements, simple instrument interface and low system complexity.

Figure 1 illustrates the cross-section of the MOS capacitor micrometeoroid detector. The detector is fabricated from a 50 to 100 mm silicon wafer. The silicon is boron-doped (p-type) to form a low resistivity substrate which becomes one plate of the capacitor. Both sides of the silicon are coated with a layer of insulating silicon dioxide (SiO_2) by a thermal oxidation process. The thickness of this oxide layer determines the energy range of particles detected by the device. Devices with thinner oxides are sensitive to lower energy particles. Common oxide thicknesses used for detectors are 4000 Å and 10,000 Å.

An aluminum coating is placed on both sides of the detector. The outer surface becomes the second electrode to the capacitor. The lower aluminum surface is used to provide electrical contact to the substrate through a hole etched in the silicon dioxide surface.

In operation, the detector is placed in the circuit shown in Figure 2. A fixed voltage is supplied to the capacitor through a one-megohm resistor. The magnitude of the voltage is selected to produce a field which is approximately 10^6 volts/cm. The impact of a particle on the upper aluminum surface will result in a partial discharge of the MOS capacitance through the dielectric in the vicinity of the impact. The high density current flow in the upper 1000 Å aluminum layer will cause the aluminum in the area of the impact to vaporize and thus effectively isolate the impacted area of the dielectric from the circuit. The capacitor will then recharge through the one-megohm resistor with a time constant of a few tenths of a second. This recharge current flows through the one-megohm resistor, producing a voltage spike which may be detected by the associated instrumentation. The size of the resistor is a parameter selected based on the desired output signal level and duration and the maximum short circuit current which can be tolerated in the case of a massive dielectric breakdown which cannot be cleared by aluminum vaporization from the stored charge.

An investigation has been conducted in which 0.5 to 5 μm diameter carbonized iron spheres traveling at velocities of 4-10 Km/sec were impacted on to detectors with either a dielectric thickness of 0.4 μm or 1.0 μm . Figure 3 is a plot of projectile diameter as a function of projectile velocity normal to the detector surface. The data shown in Figure 3 was for a dielectric of 0.4 μm and the impact angle was varied from 0 to 75 degrees. The open symbols are registered impacts while the dark symbols represent no signal or discharge. As shown the detector is very sensitive.

The craters of several of these discharges was studied with a Cameca IMS-3f ion microscope [1]. The Cameca is a direct imaging instrument capable of acquiring elemental images with lateral spatial resolution of approximately 0.5 μm . The standard ion microprobe slate has been replaced with a dual microchannel slate and a digital imaging system has been added [2,3]. High mass resolution ($M/\Delta M$, 10% valley definition) greater than 2960 was employed. High mass resolution spectrum acquired from stainless steel was used as a calibration source.

A series of ion images from the area surrounding one of the impact craters is presented in Figure 4. The images are displayed in grey scale from low ion intensity (black) to high ion intensity (white). The circular Al images delineates the 60 μm diameter image field used. The 20 μm diameter dark circular area in the center of the Al image indicates the absence of Al₂₈ resulting from the Fe particle impact. Images of ⁵⁶Fe, ²⁸Si and ²⁸Si₂ were also acquired from the same area and were found to be present within and surrounding the impact hole. As shown the ⁵⁶Fe distribution shows localized regions of high intensity and does not entirely fill the crater. Digital overlaying of the Fe and Al images indicated that some of the Fe is actually outside the impact crater as expected.

This study clearly demonstrates that the ion microprobe tuned to sufficiently high resolution can detect Fe remaining on the detector after the impact. Furthermore, it is also possible to resolve Fe ion images free of mass interferences from Si, for example, giving its spatial distribution after impact. Specifically this technique has shown that significant amounts of impacting particles remain in the crater and near it which can be analyzed for isotopic content. Further testing and calibration could lead to quantitative analysis. This study has shown that the capacitor type micrometeoroid detector is capable of not only time and flux measurements but can also be used for isotopic analysis.

References

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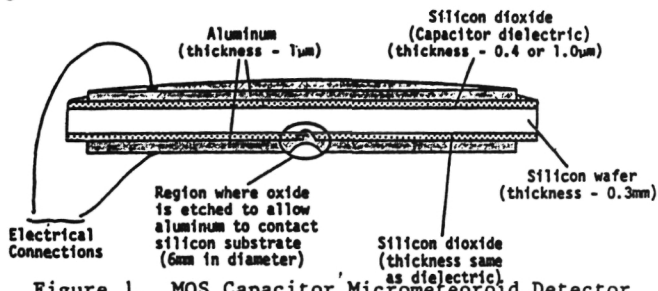


Figure 1. MOS Capacitor Micrometeoroid Detector Cross Section View.

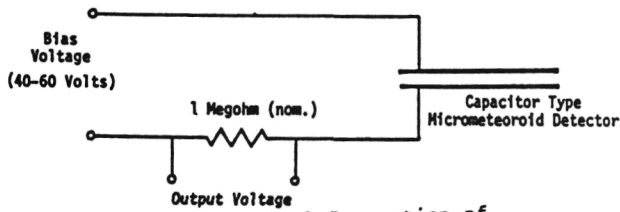


Figure 2. Electrical Connection of Micrometeoroid

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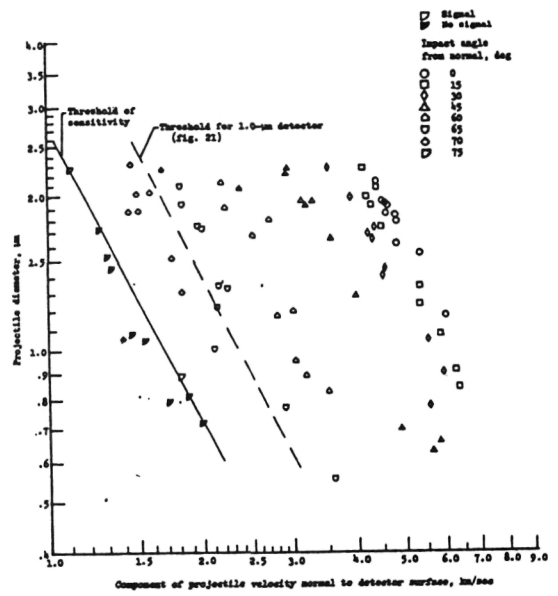


Figure 3 - Response of a 0.4-μm detector relative to projectile diameter and component of velocity normal to detector surface.

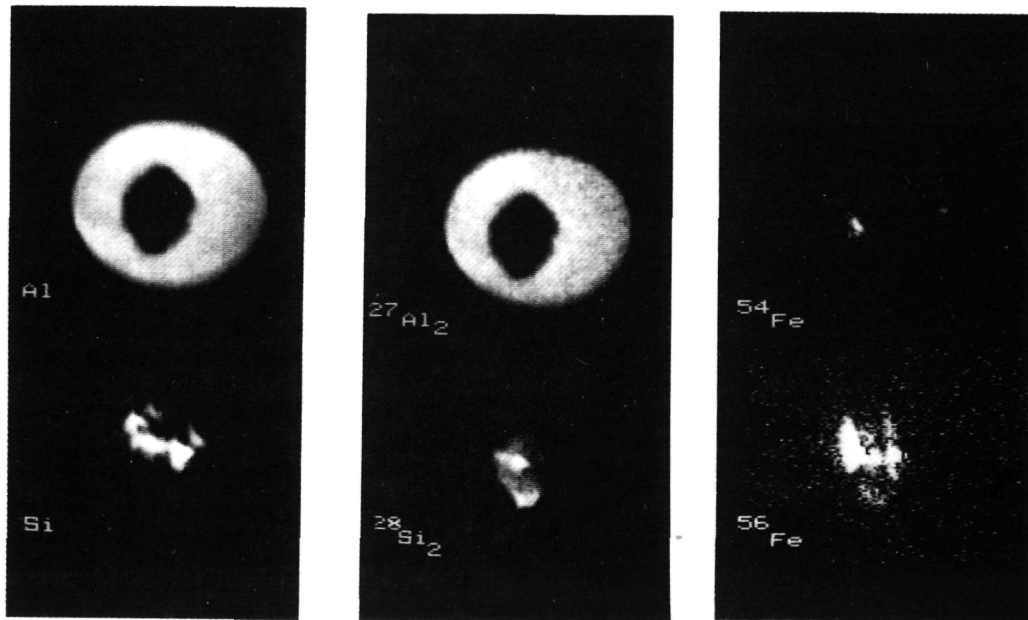


Figure 4. Secondary ion images from a 60 μm diameter area surrounding an Fe particle impact crater.